“Testing of new banknotes for machines that process currency.”

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ABSTRACT

Banknotes are now frequently used in machines. The Federal Reserve Board and the US Department of the Treasury have identified a need to produce notes that are reliably accepted in a variety of machine applications. This paper describes the steps that led to identifying requirements of manufacturers of machines that process banknotes for test notes, and the program developed for the Bureau of Engraving and Printing to address those requirements.

Keywords: Banknotes, testing, currency processing, ATMs, vending machines.

1. INTRODUCTION

For more than 15 years the Bureau of Engraving and Printing (BEP) has provided opportunities for manufacturers of equipment that processes currency (hereafter “equipment manufacturers”) to test for changes made to Federal Reserve Notes (FRNs.) Until 1996 all such changes to FRNs had been relatively minor for almost 70 years. In 1996 the Federal Reserve System issued substantially redesigned banknotes for the first time since 1929. Many machine applications have been developed that accept, dispense or process banknotes. They range from vending machines, to high stakes gambling machines, to ATMs, to sophisticated automated currency authentication and counting systems used by banks. Until the development of Series 1996 Federal Reserve Notes, equipment manufacturers were not challenged to implement major changes to equipment that processes US currency. The widespread circulation of FRNs throughout the world now causes this to be an issue not only in the United States, but also in many countries abroad.

Protection of banknotes from counterfeiting is one of the highest priorities of banknote issuers. This emphasis on the security of banknote designs has caused issuers to zealously safeguard information about changes until the time that new notes are issued to the public. The rapid and widespread proliferation of machines that process banknotes has caused a profound change in product development cycles for the BEP. In 1998 it became clear that it is now critical for the issuer of banknotes to have systems that support the public’s use of currency in machines. In the United States, this has led to the development of working relationships between the BEP and the equipment manufacturers.

The subject of this paper is the series of lessons learned by the Bureau of Engraving and Printing during the production and issuance of the latest designs for Federal Reserve Notes.

2. LESSONS LEARNED: EARLY DENOMINATIONS OF SERIES 1996

The early stages of planning for the design, testing, production and issuance of the redesigned series of FRNs was driven by factors internal to the Federal Reserve System and the US Department of the Treasury. The principal goal of the redesign was to provide the public with banknotes that were designed with features to address the threats of counterfeiting by colour copiers and digital systems. Research done by the BEP, the Federal Reserve (and other banknote authorities worldwide) indicated colour copiers and computer-based graphics systems would be the principal counterfeiting threats in the near future.

In the United States, by law, Federal Reserve Notes are required to be printed on both sides by the intaglio process. Intaglio is a traditional security printing technique utilizing steel plates and high-speed rotary presses. The BEP manufactures its intaglio plates using a combination of traditional and modern technologies. The portraits, vignettes, letters and numbers are hand engraved in steel by master engravers. The process of manufacturing the plates for production took up to 12 months for the first denominations of the new series. A number of plate assembly and production improvements have been introduced as the process of developing new currency products has become more routine for the BEP. Nevertheless, the lead-time for the manufacture of new intaglio plates remains the longest

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lead-time in the BEP currency development process. This lead-time sets the parameters for the intervals between new currency products for the United States.

One hundred dollar FRNs were selected as the first denomination for redesign because they are most frequently counterfeited. During the first year of issuance of a new design, the number of new $100 FRNs would be 13 to 15% of the notes produced by the BEP. Overall in 1995 the challenge to the BEP of producing the first complete redesign of FRNs was enormous. The production of Series 1996 $100 FRNs required a newly developed substrate in production for the first time by its manufacturer, new inks, new plates, and modifications to the face and overprinting presses. In addition, the notes of the new series have a different sequence of serial numbers. The BEP had not introduced entirely new currency products within the lifetime of anyone working there. The impact of changes of this magnitude was felt throughout the BEP's management and manufacturing systems.

The approved images for newly redesigned $100 Federal Reserve Notes were announced to the public in the fall of 1995. The first notes were issued in the spring of 1996. After the announcement, equipment manufacturers were invited to the Bureau of Engraving and Printing for a day to view the new designs, and to run them through their equipment. At this time, and for this denomination, it was critical that no images should become available to counterfeiters in advance of the issue of the notes. A breach of security would have jeopardized not only the new designs, but also the entire processing of changing Federal Reserve Notes. There was significant internal discussion as to whether to allow equipment manufacturers to process test notes through their equipment since it would result in the manufacturers having captured either images or profiles of the notes in advance of issue. The risk of premature disclosure of the new designs was controlled by sharing it only with manufacturers known to the Treasury and the Federal Reserve, and by providing a single controlled opportunity for the manufacturers to examine the Series 1996 $100 FRNs at the BEP.

Only one story about the use of new $100 FRNs in machines came back to the BEP during the early days of its circulation. In Las Vegas casinos there are machines that accept $100 FRNs. Some of these machines did not easily accept the new notes in the early days of its release. Gamblers began to hoard old series $100 notes, and the casinos did likewise. The policy of the Federal Reserve System was to remove all old series $100 FRNs from circulation so as to promote the rapid penetration of the new design. Because the gambling machines were not adequately adapted to accept the new designs, the public was inconvenienced, and the policy of rapidly withdrawing old series notes was temporarily thwarted in this environment. Although it was a limited occurrence in a unique context, it was a foreshadowing of the importance of addressing the requirements of the public for banknotes that function in machine environments.

When the new design $50 were ready for production, the BEP again invited manufacturers to its facility in Washington to examine test notes of the new design. This time each manufacturer was provided with 100 new notes to test, based on feedback from the manufacturers from the $100 experience. Testing of the $50 denomination provided the lesson that relatively small differences in the details of the printed images could impact on the assumptions made by the manufacturers in building their processing systems. A comparison of the portraits of Benjamin Franklin on the $100 FRN and Ulysses S. Grant on the $50 FRN shows Franklin's hair fills the oval frame right up to the left edge. On the $50 FRN there is a space filled with light background lines that precedes the heavy engraving of the face. These relatively minor differences caused some systems geared to the $100 image to have problems recognizing the new $50 FRN designs.

3. OUTREACH TO THE MANUFACTURERS OF CURRENCY PROCESSING EQUIPMENT

During this time period it was also becoming apparent to issuing authorities in other countries that more information was needed if they were to meet the public need for efficient use of banknotes in machine environments. The US joined with the Reserve Bank of Australia, the Bank of Canada and the Bank of England to initiate multilateral discussions with the equipment manufacturers about their needs. Meetings held between representatives of the issuing authorities and the equipment manufacturers have proven to be enormously fruitful. The issuers discovered that the equipment manufacturers were greatly interested in information about the design and manufacture of banknotes. It became apparent that the exchange of information could be managed in ways that would improve the effectiveness of banknotes in machines. The four banknote issuers involved in these exchanges have become far more knowledgeable about the use of their products, and the equipment manufacturers have means of communicating their needs to the issuers.

4. SERIES 1996 $20 FEDERAL RESERVE NOTES

In 1998 the Federal Reserve and the BEP prepared redesigned $20 FRNs for production and issuance. Twenty dollar FRNs as a denomination are the second largest volume in production and circulation (after $1 notes.) The twenty dollar FRN was the first denomination to be produced simultaneously at both facilities of the BEP. More than four billion $20 FRNS were ordered by the Federal Reserve System for production by the BEP during 1998. During the technical meetings between the issuing authorities and the equipment manufacturers, strong requests had been made to the Federal Reserve to allow the manufacturers access to more notes prior to the public release. The most compelling request was to allow the manufacturers to have access to pre-issue notes at their facilities for testing and development.

The issue of providing FRNs to equipment manufacturers prior to issuance had to be discussed and cleared at the policy level within the Federal Reserve and the US Department of the Treasury. It was concluded that the needs of the public would be better served if the equipment manufacturers were assisted in implementing equipment changes. The BEP made plans to allow the equipment manufacturers to have access to $20 test notes at the earliest possible time after the Secretary of the Treasury had approved and announced the new design. The manufacturers were welcomed at the Bureau on the day after the announcement. The BEP offered multiple opportunities for manufacturers to have access to new $20 FRNs. New procedures were pioneered that allowed the manufacturers to take 100 FRNs from the Bureau to their facilities for testing. Each manufacturer could later exchange the first 100 notes for 100 more from a later printing. It was initially contemplated that the manufacturers would be allowed to use the notes for 30 days, but as the manufacturers requested extensions of this time, the BEP agreed that the manufacturers could retain the notes until such time as the new $20 FRNs were officially issued. The equipment manufacturers were also invited to the BEP to examine sets of 1000 notes from various printings.

Despite these efforts, the early days of circulation of redesigned $20 FRNs were problematical for all those involved. Shortly before the time that the notes were to go into circulation, a number of transit authorities, and the postal service, recognized that they would have to upgrade large numbers of machines that sell farecards or stamps. Many of these machines process $20 bills. While the equipment manufacturers had been given the maximum possible amount of time for testing development and implementation of machine upgrades consistent with the schedule for issuance of the $20 FRNs, in the end it was not sufficient to allow the owners and operators of large numbers of machines to implement all the necessary changes.

The slow changeover of machines accepting $20 bills was compounded when the scale up to production of the enormous volume of $20 FRNs at the BEP had resulted in production variations that were not consistent with the test notes that had been given to the equipment manufacturers for the development of their systems. A few of the modifications made by the equipment manufacturers were unable to recognize some new $20 bills. This was a shock to the manufacturers, the BEP, and to the public. This was one of the first indications to the BEP that what had heretofore been normal variations in production characteristics of notes could have widespread negative consequences for users.

Traditionally the Bureau of Engraving and Printing had focused its resources on the greatest productivity and efficiency. The BEP manufactures a limited number of currency products in great volume. It rewards efforts to cut costs and spoilage. The traditional quality inspection systems were made up of human beings who inspected vast numbers of sheets and notes. Quality standards were based upon levels of print consistency required to promote recognition of genuine Federal Reserve Notes by human beings. Human eyes were the sensors deployed to support this quality.

The public inconvenience caused by the production variations of Series 1996 $20 FRNs brought into question the appropriateness of this inspection process for the first time. During several previous years, Bureau had been working to develop electronic inspection systems for banknotes, but the principal motivations for the work had been cost and productivity. In very short order it became apparent that the Bureau needed new tools to support its efforts to inspect for the characteristics of banknotes relevant in machine environments. As an example, ink magnetic properties are sometimes used for banknote authentication. Human eyes cannot inspect for magnetic properties. New systems had to be devised and implemented to support the application of inks in ways that would result in consistent magnetic signatures.

5. SUMMIT OF REPRESENTATIVES OF THE UNITED STATES AND OF EQUIPMENT MANUFACTURERS

By the time new $20 FRNs were released to the public, the BEP was ready to implement its program for the testing and start of production of the next denominations of new FRNs. The painful early days of $20 FRN circulation caused Bureau officials to realize that program changes would be necessary before more new designs could hit the street. New $10 and $5 FRNs were planned for the next changes. These notes are used in even more machines than $20 FRNs. The obvious first step was to meet again with the equipment manufacturers while the $20 experience was fresh.

The Bureau organised a forum to invite representatives of the equipment manufacturers to meet with policy officials and technical managers of the BEP, the Federal Reserve System and the US Secret Service. The Bureau and the Federal Reserve emphasized that the goal of the discussion was a frank exchange of information about problems from the release of past designs and potential ways to improve the process for the future. In the view of the BEP and the Federal Reserve, the meeting was a spectacular success. The manufacturers were extremely forthcoming with suggestions for improvement of the program. BEP and Federal Reserve officials were open to the information and prepared to make changes.

The BEP took the information and formulated a revised plan for the issuance of the remaining denominations of FRNs. The plan was reviewed and approved at policy levels. For the first time the schedule for the testing and production of FRNs was planned to address the needs of the equipment manufacturers. In the past, the needs of the manufacturers were fitted as well as possible into the production and issuance schedule of the BEP and the Federal Reserve.

The critical tenets of the new program were:

1. The remaining denominations of the new series should be issued all at one time. This would reduce the costs to the equipment manufacturers and to the owners and operators of machines that process currency. Potential disruptions would be minimized.

2. The equipment manufacturers would be allowed the maximum possible time between the announcement of the designs and the issuance of the new notes. It was clear that the simultaneous issue of several denominations would cause the manufacturers more work to design and install changes to equipment.

3. The manufacturers needed access to greater numbers of notes for use at their facilities, for longer periods of time.

4. The manufacturers needed more variation in the notes made available to them for testing and system development in order to reliably prepare for the variety of FRNs that exist in circulation.

5. The needs of cash dispensing machines differ from those of cash accepting machines. Manufacturers of cash dispensing machines needed access to larger quantities of notes, but could proceed without having possession of all the notes at their facilities.

6. TESTING AND PRODUCTION OF NEW DESIGN $10 AND $5 FRNS

The BEP and the Federal Reserve developed a new plan and schedule for implementation design changes to $10 and $5 FRNs. The New Currency Design staff of the BEP produced a newsletter to share information about the program with the equipment manufacturers. "Cashtalk" is sent out by the BEP from time to time to equipment manufacturers to keep information current. It was projected that the BEP would begin its internal testing process about 18 months before the notes would be issued to the public. The new plan was scoped to allow manufacturers 6 to 8 months between their first access to notes and the issue date. As with many new product ventures reality unfolded in unanticipated ways.

The value of having test notes that reflect some of the variability of the production process was clear to the Bureau as well as to manufacturers. The Bureau was developing its standards for quality control and needed information about production variability so that its internal systems would be robust enough to make informed decisions about quality. During the development of the $100s, $50s and $20s, test notes were created on one production line in the Bureau's Washington facility. The basic test unit was 20,000 sheets. Production of test notes requires interruption of manufacturing processes to use actual production equipment under normal conditions. The cost in materials and lost time and productivity is significant.

The New Currency Design staff, working with operations personnel, developed a scheme for producing decks of notes incorporating variations. The decks would include notes having a variety of characteristics that might be found in normal production. The variations were never intended to be comprehensive, or even accurately representative of actual production. The objective was to identify the most common factors that produce significant production variations and to simulate them within manageable parameters. It was agreed that the five elements elaborated below could be varied to produce test notes with useful information.

6.1 Equipment

One of the most obvious causes of note variability at the BEP is its large number of production lines. The Bureau operates 12 lines of currency production equipment, 6 at its Washington Facility and 6 in its Western Currency Facility in Fort Worth. Each line is made up of an intaglio back press, an intaglio face press, inspection equipment, a letterpress for seals and serial numbers, and packaging equipment.

Much of the equipment is Washington is almost 20 years old. The equipment in Fort Worth has been in operation less than 10 years. The intaglio presses in Washington are of an earlier generation and are equipped with far less sophisticated operating systems than the Fort Worth equipment.

6.2 Inks

There are a number of inks used by the Bureau of Engraving and Printing on Federal Reserve Notes. The greatest area of FRNs is covered by intaglio ink, on the faces and backs. The Bureau buys most virgin intaglio ink, but it recycles a great volume, by reconstituting it with fresh varnish. Although performance specifications and appearance are identical, differences can occur. At the present time, the commercial inks come from 2 plants, and the Bureau reconstitutes inks at its two facilities.

6.3 Ink density

Variations in ink density are common. They can result from equipment differences, from adjustments made for slight color variances, or for many other reasons.

6.4 People

The Bureau operates 3 shifts per day, 5 days or more per week. Even though the operating standards are the same for all sections on all shifts, operational differences can occur.

6.5 Registration

Registration variations routinely occur within the Bureau's standards for acceptable notes.

The Bureau evaluated these five elements, and the resources available in preparing a plan for test note production. Over and above these considerations, 1999 was not an ordinary production year. In anticipation of the possible high demand for currency at the end of 1999, the Federal Reserve ordered the largest number of banknotes ever to be produced by the BEP. The order was for 11.4 billion notes, almost 2 billion more notes than in recent years. The size of the order strained the production and inventory management systems of the BEP. New requirements for the development of 2 banknote designs meant that the burden of testing increased as well. And as fate would have it, in mid-year, Robert Rubin longtime Secretary of the Treasury, announced his intention to resign.

7. TEST DECK CHARACTERISTICS

The plan for decks of test notes was based on allowing each manufacturer 1000 test notes of each denomination. The 1000 notes would include 100 notes in each of 10 variations. The variations were chosen for a combination of elements feasible within the BEP production system that would provide information about variations in equipment, inks and processing conditions.

The production variations were originally planned to include:

Intaglio

2 back presses in Washington; 2 back presses in Fort Worth

2 face presses in Washington; 2 face presses in Fort Worth

Inspection

Electronic inspection at both facilities

Overprinting

2 overprinting presses at each of Washington and Fort Worth

Intaglio Ink

Ink from the Bureau's commercial supplier for both faces and backs. Ink would come from both facilities operated by the supplier.

Reconstituted ink manufactured by the Bureau at both of its facilities.

Registration

Registration variations at overprinting

Ink density

Intaglio inks applied in high, normal and low densities

8. LESSONS LEARNED FROM TEST DECK PRODUCTION

The Bureau began its test printings for the new $10 and $5 FRNs in Washington in the spring of 1999. As might be expected with initial product testing, a number of issues were identified with the processes and materials. These issues were being addressed at the point when the resignation of the Secretary of the Treasury was announced. The signature of the Secretary of the Treasury is a design element of the intaglio plates used to manufacture FRNs. Normally the BEP continues to use its stock of plates with the signature of an existing Secretary until new plates are available. However in this instance no new design $10 or $5 notes had ever been issued with the signature of Secretary Rubin. The only such notes that existed had been created as part of the production test run. Ten dollar and five dollar test plates had to be recreated with the signature of the new Secretary of the Treasury, Lawrence Summers. There was the added challenge of creating the engraving of his signature before plate production could recommence. In the interim equipment manufacturers were anxious for notes to begin development of the equipment changes that would be required for the two new denominations. It was decided to allow the equipment manufacturers to come to the Bureau to examine notes with Secretary Rubin's signature in August 1999.

After Labor Day, new plates with Secretary Summers' signature were created and the process of making the test decks began anew. Test notes would be created in both Washington and Fort Worth. But as the time approached for the test runs a number of events occurred that caused the scope of the tests to be modified again. Because of the events during the summer of 1999, additional production of the test decks had to be scheduled for the final 60 days of the Bureau's production year. By that time, it was critical for the Federal Reserve to receive all of the 11.4 billion notes that it had ordered for the year. Demand for currency during the third quarter suggested that all of the planned inventory would be required. Taken together, these demands strained the Bureau's production capacity. The need to produce test decks for the equipment manufacturers was viewed as critical. The best compromise was to scale back some of the initial components of the test decks plan to include the components listed below.

Intaglio

1 line in Washington and 1 line in Fort Worth. Plate changes were used to produce some variation in intaglio print characteristics.

Inspection

Electronic inspection at both facilities

Overprinting

1 overprinting press at each of Washington and Fort Worth

Intaglio Ink

Ink from the Bureau's commercial supplier and several formulations of reconstituted ink manufactured by the Bureau.

Registration

Registration variations at overprinting

Ink density

Intaglio inks were applied in high, normal and low densities

9. FINAL OBSERVATIONS

Secretary Summers announced the issuance of the redesigned $10 and $5 FRN in November 1999. The test decks were distributed to the equipment manufacturers in December 1999. It is expected that the new notes will be issued in late spring or early summer 2000. The equipment manufacturers will have had access to the designs since August 1999, and they will have a significant number of notes for evaluation at their facilities for six months or more before the public tries to use the new $10 and $5 FRNs in machines. Manufacturers of cash dispensing machines were able to test 15,000 notes of each denomination at the Currency Technology Office of the Federal Reserve System in Richmond, Virginia.

The Bureau of Engraving and Printing learned a number of new lessons while developing the test decks. The New Currency Design test team deployed four experienced senior project managers full time for the better part of a year in the planning and production of the test decks. Countless hours were spent coordinating with production planning, production support, operations, security and accountability components of the Bureau. The Bureau and the Federal Reserve created an entirely new series of procedures to account for the delivery large numbers of FRNs outside of the Federal Reserve System prior to the issue date. The development and implementation of the policies required extensive coordination at policy levels of the Treasury and Federal Reserve.

The resources needed for the actual production run were greater than originally anticipated. The test notes were planned to be produced in runs of 10,000 sheets for each denomination in each plant. While it took several hours to set up and conduct a test run, 10,000 sheets are too few sheets to efficiently equilibrate the presses. The plan to change ink densities, registration and plates further reduced the amount of time available for uninterrupted running of the presses. Some runs extended over more than one shift. The changes of personnel and related accountability requirements caused further disruptions in smooth running of the tests.

Personnel and systems of the BEP ensure that every sheet and every test note is accounted for throughout the production process. Inventory tracking transactions are recorded with every movement of the materials. The project manager and a security representative are present 100% of the time while test materials are outside of the vaults. The creation of the test decks exponentially increased the accountability burden as dozens of packages of small numbers of sheets were separately created and stored. The test materials were audited. It was found that additional steps were necessary to ensure complete tracking of these small packages of test sheets.

The Bureau's electro-machinists built a new device to track test notes going to the equipment manufacturers. The imaging equipment records the serial numbers of every test note. The database is used to verify the specific notes in a given package and provides a means to track the location and recipients of all test notes. Two dozen equipment manufacturers obtained 1000 notes of each of two denominations.

The Bureau and the Federal Reserve remain concerned about the security of the new designs prior to issuance. All equipment manufacturers receiving notes are known to the Bureau or are investigated by the US Secret Service. Every company is required to sign security agreements including non-disclosure covenants and restrictions on the handling and use of the notes prior to the official issue date. Those within the company having a need to know may use the notes only for authorized purposes. The companies were required to pay for the notes, but may return them to the Bureau and have the money refunded.

All of these steps were taken to provide better-functioning banknotes to the public. Additional efforts will be undertaken by the US Treasury during the coming months to educate the owners and operators of currency handling machines about the need to upgrade equipment in time to handle the redesigned $10s and $5s. The Federal Reserve System and the Treasury want FRNs to work in machines the first time, and every time thereafter.

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